1st Spanish National Conference on Advances in Materials Recycling and Eco – Energy
Madrid, 12-13 November 2009
S04-13

USE OF CERAMIC WASTES IN STRUCTURALS CONCRETES

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Abstract

The aim of this paper is to describe how waste material produced by the sanitary ceramics industry can be reused as aggregate in structural concrete mixes, as well as to analyse the economic and environmental benefits of this reuse. Firstly, aggregates were classified in order to assess their suitability for concrete mixing. Once the necessary assays had been carried out, different mixes were produced by gradually substituting part of the natural coarse aggregate with the recycled ceramic material. These concrete mixes were tested to determine their structural properties and results show that we can be optimistic when considering use of this kind of waste material in structural concrete.

Keywords: Recycling, environment, waste products, aggregates, concrete

INTRODUCTION

Recent decades have seen a marked upsurge in industrial and economic growth, contributing to an improved quality of life and well-being for citizens. However, we should not lose sight of the fact that every production system creates by-products and waste products which can affect the environment. These effects may occur at any point in the product's life-cycle, whether during the initial phase of obtaining raw materials, during the transformation and production phase, during product distribution or when the end user must dispose of products which are no longer required.

In recent years [12], initiatives have been instigated on a global and national level [7] to control and regulate waste management. Regulations have become increasingly rigorous and consequently, options which are still rarely used at present, such as minimizing or recycling waste, are becoming economically attractive. All recycling and reuse of waste products involves research aimed at acquiring a full understanding of such products in order to determine suitable and specific applications.

Spain is the world leader in the sanitary ceramics market, and in 2007 [13], these goods represented 9% of the Spanish ceramic industry's production revenue, only outstripped by sub-sectors specialising in the manufacture of wall and floor tiles, and bricks and roofing tiles.

This industry produces over 7 million items of sanitary ceramics a year (2007), and generates approximately 24 t of waste a month. The percentage of products which are deemed unsaleable and therefore discarded depends on the type of plant and product requirements. Such non-hazardous industrial wastes (NHIW) are classified in the European List of Wastes [6] as codes 10 and 12; "*Waste from the manufacture of ceramic products, bricks, roofing tiles and building materials"*

Sanitary ceramics, as with all other ceramic products, are produced from natural materials which generally contain kaolin, china clay, feldspar, potassium, and quartz [10].

In previous studies carried out by different research teams, material of ceramic origin has been used as road fill [5], as a partial substitute for natural aggregate
in concrete, either as coarse aggregate [2, 3, ,14] or as fine aggregate [1,11], and as a substitute – in varying proportions – for cement in mortar and concrete [8, 9,12].

The aim of the present research is to analyse the possibility of reusing all of this industrial waste in structural concretes, substituting varying percentages of natural aggregates.

EXPERIMENTAL

Materials

Siliceous natural aggregates were used, with a maximum size of 20 mm, and the cement employed was CEM I 52.5 R. The recycled aggregates were first crushed using a jaw crusher, and then sieved to remove any fragments of 4 mm or less in size. The remaining fraction of recycled aggregate was used in varying proportions to substitute conventional coarse aggregates, following the recommendations indicated in Annex 15 of the EHE-08 [4].

Aggregate assays

In order to confirm that the materials complied with the requisites indicated in chapter VI of EHE – 08 [4], the different physical and mechanical properties of both the natural and the recycled aggregates were determined prior to their use in concrete mixes, by carrying out the various assays specified in the relevant UNE standards. In addition, porosity of both types of aggregate was determined, using the technique known as mercury porosimetry. A Micrometrics 9500 porosimeter was used, which reaches a pressure of 33,000 psia (228 MPa), capable of determining pore size within a range of 6 to 0.005 μm.

Lastly, the crystalline structures present in the recycled ceramic aggregate were identified through X-ray diffraction (XRD), using a BRUKER D8 Advance Theta-Theta diffractometer without monochrome and with a 2.2 kW Cu anode.

Concrete assays

The samples taken from the various concrete mixes were all mixed, cured and tested according to the specifications indicated in the UNE standards currently in force. The assays were primarily directed toward determining compressive strength, this being the most frequently measured mechanical property of structural concretes. In addition, indirect tensile strength values were obtained using the Brazilian Test. The various samples were tested at 7, 28 and 90 days.

RESULTS AND DISCUSSION

Various aggregate assays were performed with the aim of determining whether the values fell within the limits established in chapter VI of EHE-08 [4]. The results obtained are shown in the following table. As can be seen, the aggregates fulfilled the requirements in all cases.

Table 1. General, physical and mechanical properties of the coarse aggregates

PROPERTY	GRAVEL	CERAMIC	EHE – 08 REQUIREMENTS
Maximum size (mm) (*according to UNE EN 933 – 2*)	20	16	-
Quantity fine aggregate passing through 0.063 μm mesh (% coarse aggregate weight)	0.22	0.6	1.5 %
Density (kg/dm³) (*according to UNE EN 1097 – 6*)	2.64	2.41	-
Water Absorption Coefficient (%) (*according to UNE EN 1097 – 6*)	0.23	0.55	$\leq$ 5 %
Total porosity (%) (mercury porosimetry test)	0.23	0.32	-
Elongation Index (%) (*according to UNE EN 933 - 3*)	3	23	$\leq$ 35
Los Angeles coefficient (%) (*according to UNE EN 1097 – 2*)	33	20	$\leq$ 40

As regards the results obtained through x-ray diffraction, Figure 1 shows a diffractogram of the ceramic aggregate sample, in which the various phases encountered have been labelled.

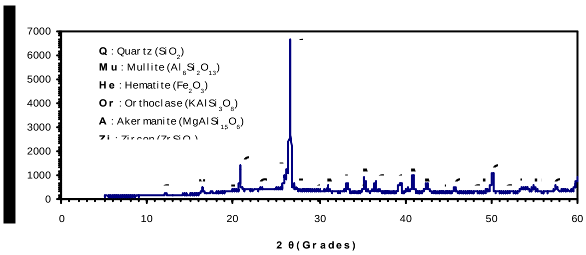

Figure 1. Diffractogram of recycled ceramic aggregate

To conclude this section, it should be noted that the results obtained in the compressive and tensile strength tests revealed that strength values increased as the proportion of natural coarse aggregates substituted by recycled aggregates rose.

CONCLUSIONS

A detailed analysis of the results obtained in the various assays has led to the following initial conclusions:

- Recycled aggregates obtained from industrial waste produced by the sanitary ceramics industry are suitable for the manufacture of concrete.

- Recycled concrete obtained through partial substitution of natural coarse aggregate is suitable for structural purposes.

As a consequence of these results, the following works could be carried out:

- Further mechanical assays are necessary, as are assays testing durability and microstructure, among others.
- Introduction of fine recycled aggregates as partial substitution for fine natural aggregates (sand).

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ACKNOWLEDGEMENTS

The authors would like to thank Maria Isabel Sánchez de Rojas and Moisés Frías Rojas, of the IETcc, for their collaboration, and for providing advice and guidance at all times as well as enabling us to carry out the various assays at the IETcc facilities. We would also like to thank Cerámicas GALA S.A. for supplying material free of charge and for providing all information requested.